Current Status of Prosthetic Cardiac Valves

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■ *The majority of patients with acquired valvular heart disease have severe damage to valves which is not amenable to repair but can now be treated by valve replacement with an acceptable mortality and morbidity.*

The caged ball or disc valve is widely used and is proving clinically satisfactory for cardiac valve replacement. Thromboembolism is the significant complication. With improvement in technique the incidence of infection, detachment and other complications has been reduced.

THE NEW FRONTIER in cardiac surgery is the development and implantation of heart valves. The success of the heart-lung machine has changed the surgical treatment of heart disease so that blind (closed) techniques have given way to open methods of surgical operations on valves—commissurotomy, annuloplasty, sculpturing and now valve replacement.

Enthusiasm was short-lived for debridement or sculpturing of calcified valves, or replacement of one or more cusps by dacron and teflon leaflets, as it became apparent that they entailed a high incidence of late complications—stiffening, recalcification, cracking or detachment of cusps. The ball valve (Figure 1) introduced in 1954 by Hufnagel[8] for use in the proximal descending aorta has been modified and developed in the last five years so that it can now be implanted in the anatomically correct position.

Types of Valves in Current Use

Ball Valve

Harken in 1960[5] introduced the caged ball valve, which was improved by Starr and Edwards[12] and further modifications made by others. The Starr-Edwards ball valve (Figure 2) is at present the most widely used prosthetic device for replacing mitral, aortic and tricuspid valves, more than thirty thousand valves having been distributed by the manufacturer in the last five years. The simple rugged mechanism consists of a silicone rubber sphere contained within a cage of Stellite 21® (a vitallium-like alloy) which is fixed to the

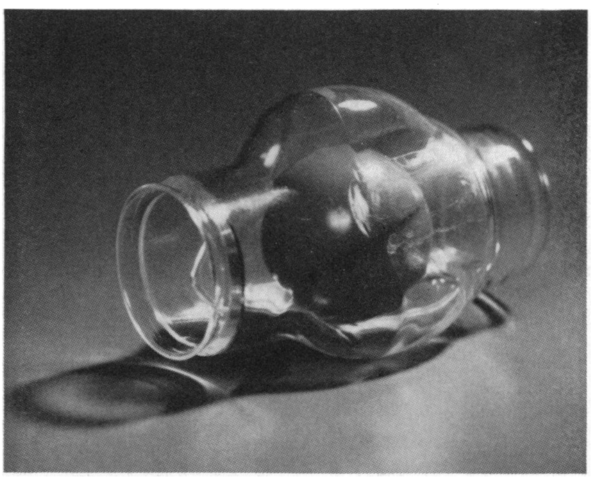

Figure 1.—Hufnagel valve, the prototype of the present ball valve. When such valves were used they were inserted into the proximal descending aorta for aortic insufficiency.

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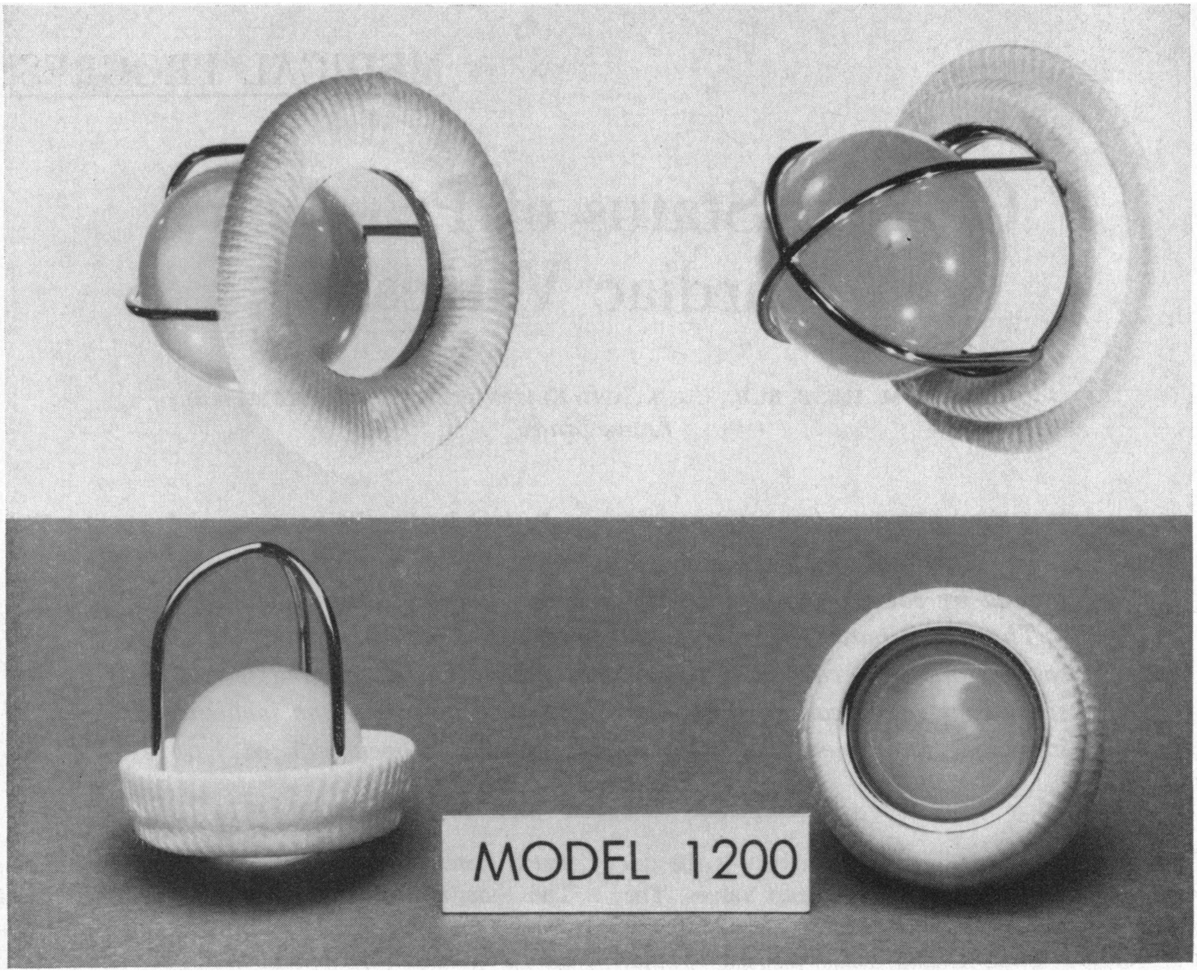

Figure 2.—Starr-Edwards valves. Two views of mitral valve (above) and of aortic valve (below).

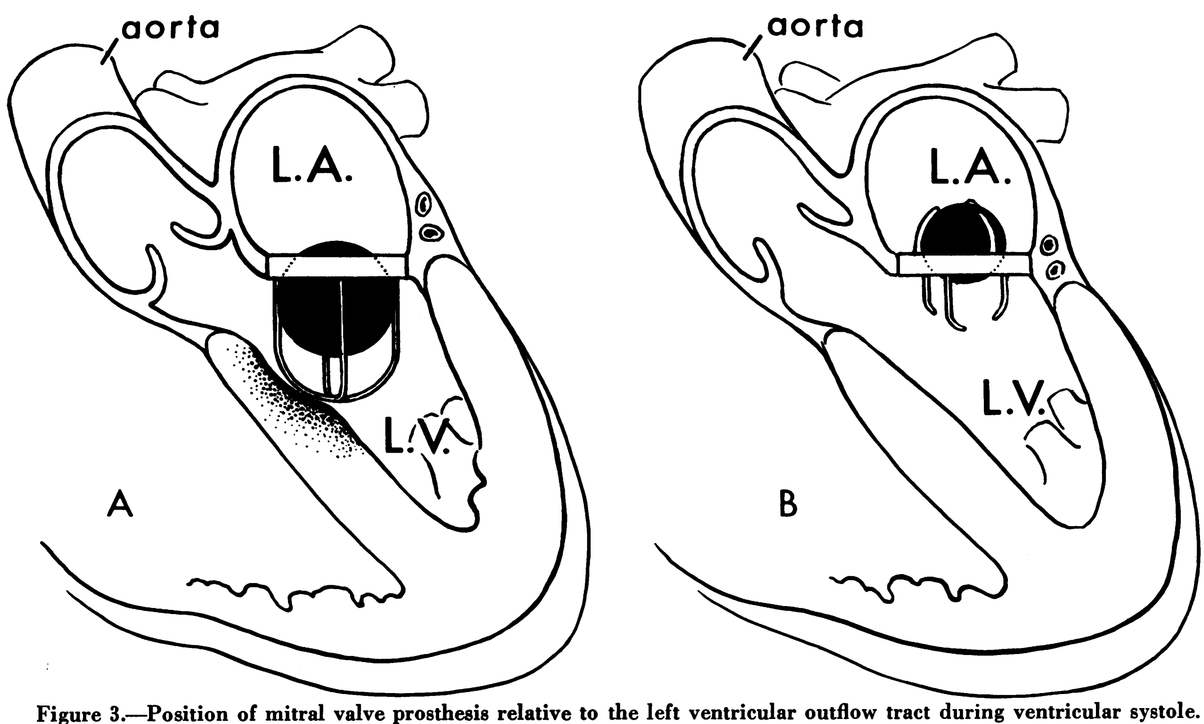

Figure 3.—Position of mitral valve prosthesis relative to the left ventricular outflow tract during ventricular systole. Starr-Edwards valve (left) and Smeloff-Cutler valve (right).

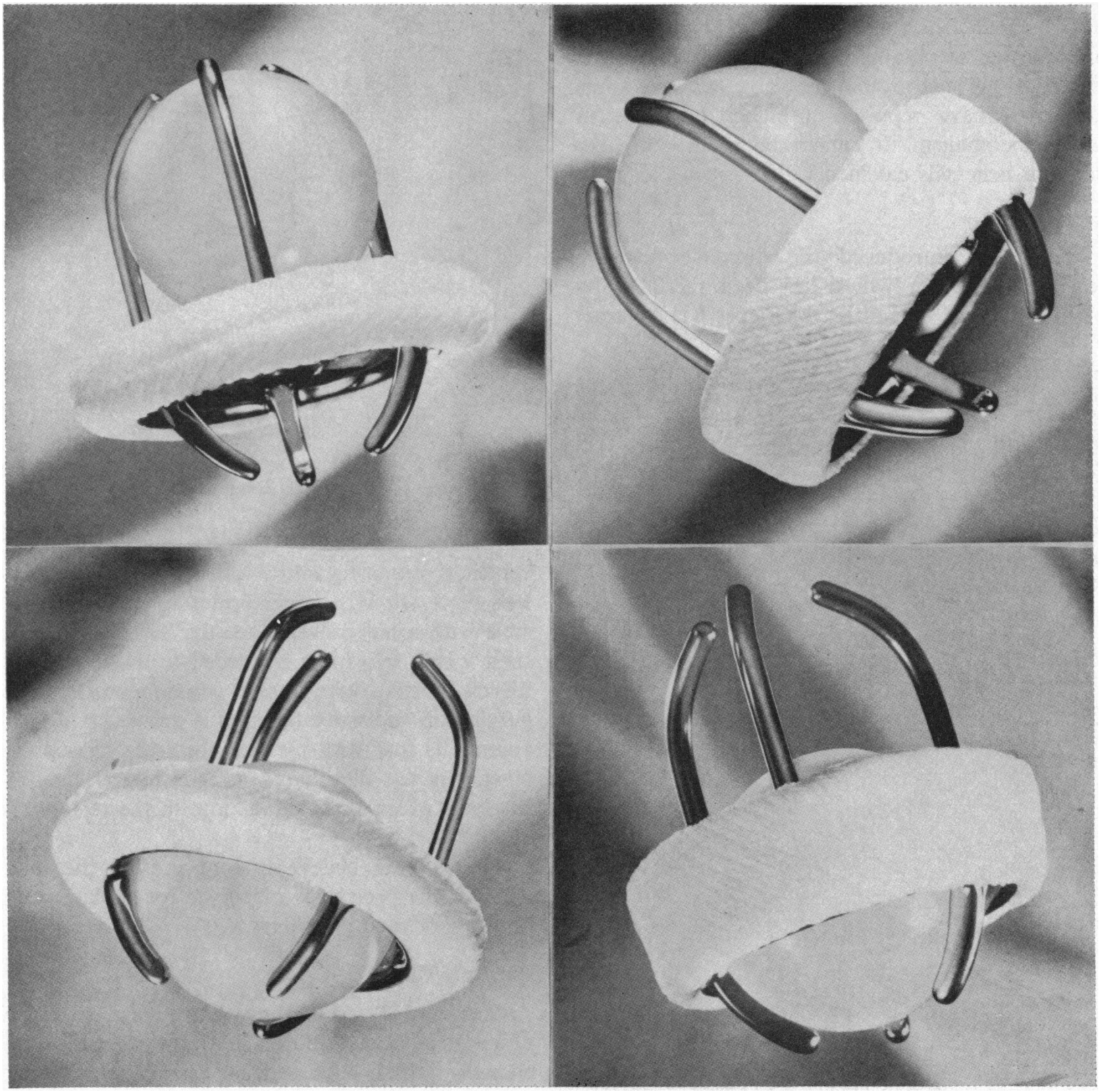

Figure 4.—Smeloff-Cutter valve. Open and closed views of mitral valve (left frames) and of aortic valve (right frames).

host tissue by sutures through a short cuff of teflon cloth attached to the base of the prosthesis. This valve has disadvantages, including the limited size of the orifice as a seat for the ball and the fact that the ball itself causes some obstruction in the ejection path. When implanted in the mitral position, the ball is located in the outflow tract of the left ventricle (Figure 3) and may also cause obstruction to the emptying of this chamber. The inertia of the ball makes it less efficient during times of tachycardia. Thromboembolism, infection and hemorrhage from anti-coagulants have all been problems.

Smeloff and Cartwright[3] designed a ball valve (Figure 4) with a wider diameter orifice and a double cage. It has up to 78 per cent larger orifice area than the Starr devices of comparable external diameter; hence this valve has particular advantage in patients with a small aortic annulus. In the mitral position the ball seats deeper into the atrium and thus causes less obstruction to the emptying of the left ventricle (Figure 3). Claims have been made that this valve is associated with a lower incidence of thromboembolic complications.

Magovern[10] developed a valve (Figure 5) utilizing rapid nonsuture mechanical fixation. Multiple curved pins are projected into the surrounding tissue when the valve is placed in the desired position. This valve has its place in the management of the very poor risk patient, where speed of insertion is paramount. There is an increased incidence of leak around the valve and also some observers have reported a higher incidence of thromboembolism. It cannot be used where the annulus is heavily calcified.

Disc Valve

Hufnagel[7] introduced the discoid prosthetic valve (Figure 6) which has been modified by Cross[4] (Figure 7) and Kay[9] (Figure 8), Alvarez[1]

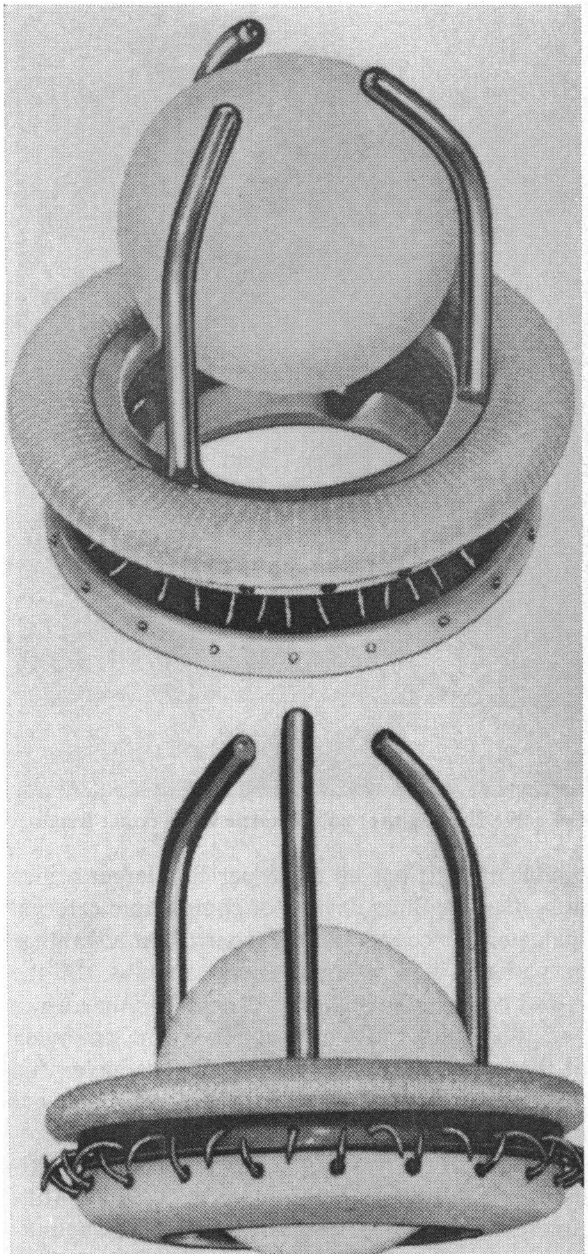

Figure 5.—Magovern sutureless valve with pins retracted (above) and pins extruded (below).

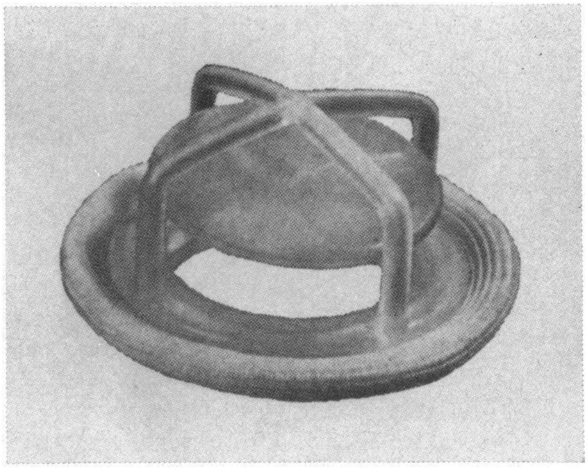

Figure 6.—Disc valve developed by Hufnagel.

(Figure 9) and others. In hearts with a small left ventricle, requiring mitral valve replacement, the lens valve allows a larger orifice size than is possible with a ball valve. Since the lens weighs less than a ball, less force is needed to overcome the valve's inertia; there is as a consequence less regurgitation and valve function is quieter. A disadvantage is that with the lens the wear caused by closure is not distributed as it is in the case of the ball, which turns at random in the stream of blood.

The authors believe that at present the disc valve is the prosthesis of choice for replacement of mitral or tricuspid valves.

Butterfly Valve

Gott and Daggett[6] have introduced a valve (Figure 10) with hinged butterfly leaflets. Not enough time has passed to determine whether stiffening or cracking of the flexible leaflets will develop. Thrombosis has been a problem despite adsorbtion of heparin on the valve base and use of anticoagulants.

Homografts

Homografts are being used for replacement of the aortic valve and experimentally for mitral valve replacement. Barratt-Boyes[2] and Ross[11] reported excellent early and late results with the aortic valve. One wonders whether the leaflets will stiffen and crack or possibly shrink or calcify. It is important to use exactly the right size valve to avoid gross insufficiency. Bacterial endocarditis is a problem with this, as with other prosthetic valves, but the incidence of thromboembolism appears to be less.

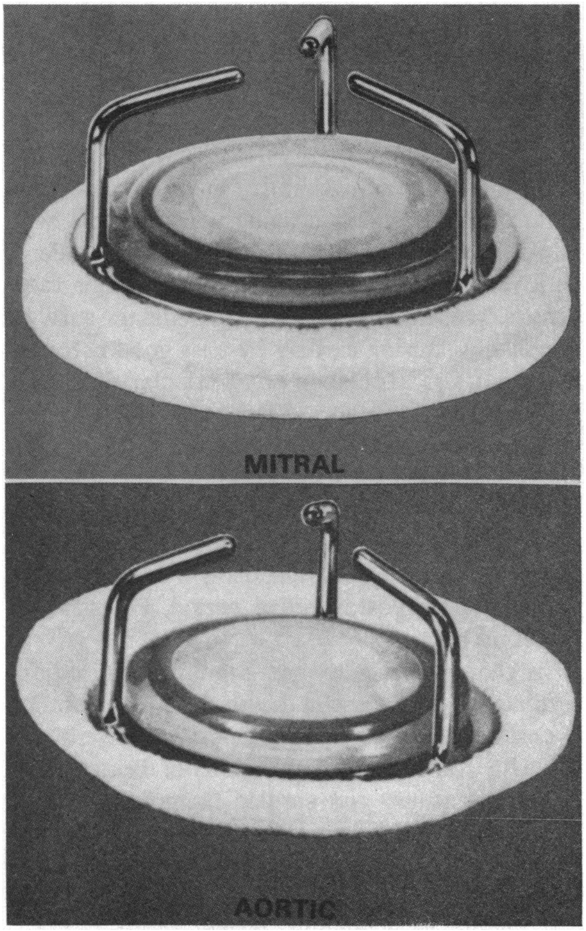

Figure 7.—Cross-Jones disc valves.

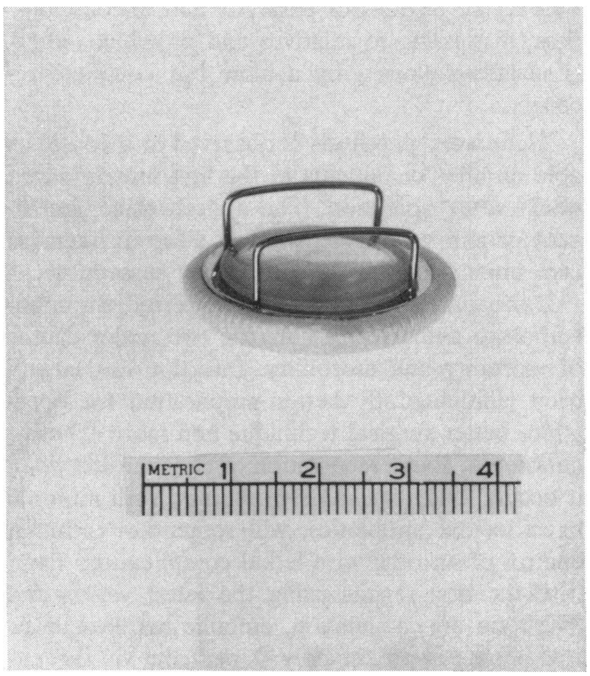

Figure 8.—Kay-Shiley disc valve.

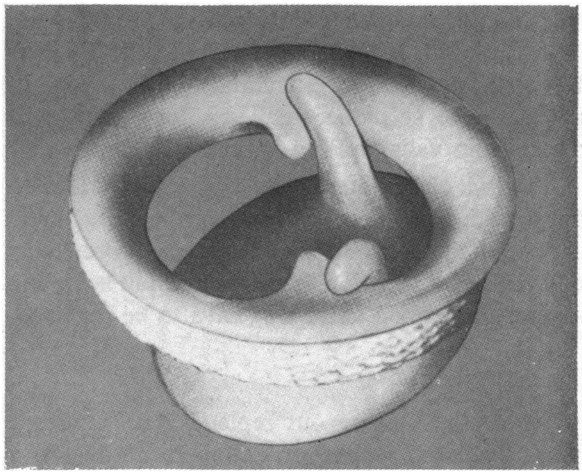

Figure 9.—Alvarez valve.

New Valve Designs

To overcome the threat of thrombosis and embolism, attempts are being made to design valves in which cloth covers as much as possible of the prosthetic device, providing a mesh for firm attachment of the endothelium. The newer Starr valve illustrates this trend in that its base is largely covered by the cloth attachment ring. The other approach is to make the valve with a surface that is resistant to clot formation, the Gott-Daggett valve being an attempt in this direction.

Current Indications for Use

Mitral Valve

Finger and instrumental commissurotomy continues to be the standard procedure for mitral

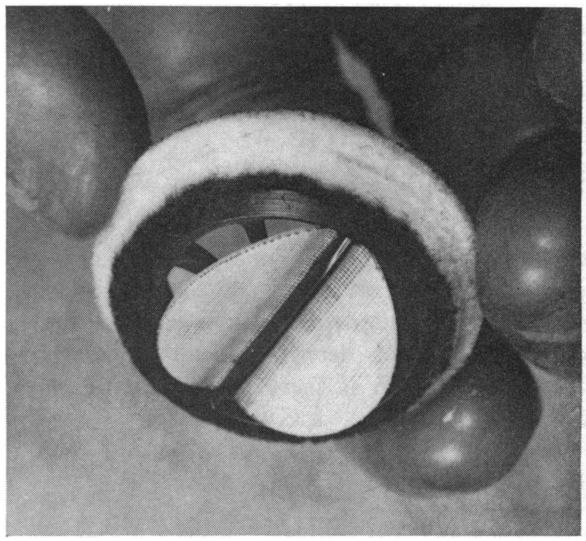

Figure 10.—Gott-Daggett "Butterfly" leaflet valve.

stenosis. Replacement of the valve is reserved for cases in which there is dense calcification of leaflets or in which chordae tendinae or loss or shrinkage of valve substance makes a long-term good result from valvuloplasty impossible.

The widely dilated but minimally deformed valve with mitral insufficiency, either congenital or acquired, can usually be made completely competent by plication-annuloplasty, but again the severely deformed valve will have to be replaced.

Aortic Valve

The authors carry out replacement in all patients operated upon for acquired aortic valve disease, since reconstruction of this valve generally has proved unsatisfactory. Congenital aortic stenosis is treated by commissurotomy unless calcification makes replacement necessary. Rarely, congenital aortic insufficiency is an indication for valve replacement.

Tricuspid Valve

Ebstein's anomaly is surgically treated by placing a prosthetic valve in the true atrio-ventricular position. Tricuspid disease, managed essentially like mitral disease, is usually associated with other valve defects. In very large hearts it results from annular dilatation.

Multiple Valve Operations

In rheumatic heart disease, multiple valve involvement is common. A few years ago multiple valve replacement carried a high mortality. However, experience and improved techniques have enabled many severely disabled patients to make a satisfactory recovery, some centers reporting a risk not significantly greater than that associated with single valve insertion.

Contraindications

Serious associated conditions such as cirrhosis, chronic renal failure, pulmonary fibrosis and emphysema may be severe enough to contraindicate open heart operations. Intractable cardiac failure, once felt to be a deterring factor, is not now a contraindication if there are significant valve lesions.

Results

In the last four years there has been a considerable decrease in the risk of operations to install prosthetic valves. The early hospital mortality should be under 10 per cent with a late mortality about the same.

Complications

In the early postoperative period myocardial failure may occur, particularly in patients with mitral insufficiency, class IV patients and patients with very large hearts. Unless all the major valve defects are corrected in these patients, survival is unlikely. During cardiac by-pass good coronary perfusion and avoidance of ventricular distension will protect the myocardium, and after by-pass the administration of isoproterenol (Isuprel®) is useful for myocardial support.

Arrhythmias will be seen less frequently if the patients are somewhat under-digitalized at the time of operation and maintained on a lower dose in the immediate postoperative period. Potassium is useful in therapy.

In the patient who has been heparinized for cardiac by-pass, careful hemostasis at operation is essential to avoid excessive postoperative bleeding with associated complications of hemothorax, hemopericardium and cardiac tamponade.

Air embolus to coronary and cerebral arteries can be prevented only by the most exhaustive use of vents and extremely careful attention to fine details of technique. It will result in myocardial and cerebral damage. The latter, manifest by varying degrees of paralysis and unconsciousness, distressing to relatives and physicians alike, is usually followed by a slow but complete recovery.

Temporary psychosis is observed in a considerable number of patients in the first few days and weeks after operation. The apprehensive, intelligent patient who is deprived of sleep in intensive care units seems to be particularly susceptible.

During the late postoperative period thromboembolism and infection are the two major causes of mortality and morbidity. Infection has largely been eliminated by better preparation for operation, better surgical technique and more effective antibiotics. Early recognition of endocarditis when it occurs, and then massive therapy with multiple bacteriocidal antibiotics, will sometimes result in control of an otherwise lethal complication. Even with the best results using the latest valves and long-term anticoagulation, embolic manifestations still plague approximately 9 per cent of the patients, although fortunately serious neurological deficits rarely persist. Thromboembolism remains as the major challenge and stimulus for the development of new and better prosthetic valves. Coronary insufficiency, seen particularly in patients with aortic valve disease, results in some late deaths.

Hemolytic anemia occurs occasionally due to the pronounced turbulence created by the prosthetic device, particularly when insufficiency is also present.

Hepatitis remains an ever-present danger where donor blood is used. However, with the glucose-prime disposable oxygenators, transfusion requirements of blood are decidedly less than they used to be, and even double valve replacement has been successfully performed without use of blood or blood derivatives in patients who on religious grounds refused to permit their use.

Late cardiac failure—after three months—is almost always due to complications of the prosthetic valve and may necessitate reoperation to correct detachment.

Discussion

The surgical installation of prosthetic valves has contributed significantly to the rehabilitation of thousands of cardiac cripples and most of these patients have escaped serious complications. While great strides have been made in the development of prosthetic heart valves, improvement still is necessary before the ideal valve is reached.

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